APPLICATIONS OF THE BREEDING BIRD SURVEY (BBS) IN BASELINE AND MONITORING STUDIES[1]

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[1]Paper presented at the Bird Census Symposium, Asilomar, California, October 27-31, 1980

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Abstract: Habitats and avian communities were studied in a mixed-grass prairie region of northeastern Montana for four years beginning in 1977. Five BBS routes (one experimental, four controls) were run monthly during 1977 and three times during the breeding season each subsequent year. The large sample sizes allowed many ecological parameters to be statistically examined, including: habitat relations; changes in abundances of individual species; trophic structure; resident status; and diversity. Bird community parameters sampled by the different routes were found to maintain a distinct ordination relative to one another, which remained fairly constant from year to year in spite of wide fluctuations in weather, vegetation, and abundances of individual species. The method was found to be over 91% effective in sampling breeding bird species composition in a large study area over a four-year period. The species abundance relation of the bird communities sampled provided a precise "fingerprint" of community structure which was very closely related to such parameters as species number and diversity, and which changed remarkably little from year to year in the absence of disturbance. Although development has not yet occurred in the study area, the method should be very sensitive in detecting development-related impacts to terrestrial ecosystems.

INTRODUCTION

The goal of many wildlife baseline and monitoring studies is to provide a "yardstick" by which pre- and post-development conditions may be statistically compared. This type of study is often required by law in order to (1) compare actual impacts with earlier predictions, (2) document unforeseen effects, (3) evaluate the effectiveness of mitigation or compensation, and (4) determine possible noncompliance with permit stipulations. A simple, sensitive, and cost-effective method allowing pre- and post-construction monitoring of terrestrial ecosystems to meet these objectives is desirable.

The breeding bird survey (BBS), described by Robbins and Van Velzen (1967, 1969), may be the ideal method for monitoring wildlife communities. This method allows repeatable, quantitative measurement of bird communities to be made over an area of 25.4 km^2, including a variety of habitats, in about four hours. Since its initiation in 1968, it has come to be used

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yearly in all 50 states. In 1979 over 1,800 BBS routes were run in the United States with an additional 230 routes in Canada. Use of the method therefore provides the opportunity to tie into a vast amount of data gathered nationwide using a carefully standardized methodology. The method has recently been used in studies of bird ecology (Peterson 1975, Wiens and Dyer 1975, Weber and Theberge 1977, Rotenberry 1978, Rotenberry and Wiens 1978) and in a few baseline wildlife studies (e.g., Lewis et al. 1978, Matthew 1979, Preston and Thompson 1979), but it has not yet been widely used in long-term monitoring. The purpose of this paper is to show how several different kinds of valuable ecological information can be extracted from BBS data, and how the BBS can be used effectively and with statistical reliability in environmental baseline and monitoring work.

Sincere thanks are extended to the many individuals who kindly assisted in the field work, and to Rich Prodgers for sharing his data on vegetation and habitats. George Cawlfield and Ed Madej provided invaluable aid in data analysis, and June Virag produced the graphics. Field work was funded by Northern Resources, Inc.

BIRD COMMUNITIES AS ENVIRONMENTAL INDICATORS

The choice of breeding birds as a taxon capable of indicating overall environmental conditions is well justified (Graber and Graber 1976). Most temperate birds are territorial during the breeding season, and are quite habitat and site-specific in selecting a territory. Birds are generally very vocal and conspicuous at this time, and can be detected and identified instantly at fairly large distances during daylight hours without special collecting equipment, unlike most mammals, herps, and insects. They represent many guilds and many trophic levels from strict herbivores to top-level carnivores. More species of birds are generally found in a given area than other vertebrate taxa, allowing a large community sample size.

The use of single "steno" species as indicators of specific environmental conditions (especially of certain vegetation zones or types) has been discussed by Daubenmire (1968), Odum (1971) and Graul et al. (1976). Regarding the use of animal species as indicators, Ehrenfeld (1976) has said, "the mere presence of a given species or group of species in a particular environment can be used to define normal or baseline environmental conditions and to determine the degree to which communities have been affected by...influences such as pollution or man-made habitat alteration." However, one might expect the structure of multi-species communities to be an even more sensitive indicator of environmental conditions (Nagasawa and Nuorteva 1974); populations of single species often fluctuate drastically from year to year, but overall community structure would be expected to more closely reflect environmental conditions and, in the absence of environmental stress, to be perhaps more constant from year to year. Ehrenfeld (1978) states that "Biological functions such as the diversity of species in a particular location when studied over a period of years are the best possible indicators of the meaningful effects of pollution, just as the behavior of an animal is the best single indicator of the health of its nervous and musculoskeletal systems. Species diversity is a resultant of all forces that impinge on ecosystems. It performs an automatic end product analysis."

Jarvinen and Vaisanen (1976) found that bird species diversity, for example, is remarkably stable from year to year in spite of annual fluctuations in populations of individual species.

One would expect bird community structure to be indirectly but measurably affected by any change in 1) habitat quality or extent, 2) habitat vertical structure and patchiness, 3) food availability (seeds, insects, rodents, other birds), 4) density of competitors and predators (man, skunks, coyotes, deer, other birds, etc.), and 5) the intensity of disturbances such as noise, dust, other pollutants, and traffic.

The synergistic effects of several such changes occurring together should have an especially marked influence. Therefore, in baseline or monitoring studies, we can let the birds do the work of carefully measuring an entire constellation of variables related to environmental quality--which they have been programmed to do with extreme precision through millenia of selection--and we simply measure the birds. Despite the theoretical appeal of using bird community parameters as an indicator of environmental stress or change, few long-term studies have actually attempted this (see, for example, Nagasawa and Nuorteva 1974, Adams and Barrett 1976, Moulding 1976).

STUDY AREA AND METHODS

This study was conducted in McCone County, Montana, an area best characterized as mixed grass prairie. Elevations in the study area range from 604 m to 878 m and average annual precipitation ranges from 30 to 41 cm/yr. Five BBS routes were established in the study area (Figure 1). Four of the five routes were chosen non-randomly, and were located on the basis of year-long accessibility, variety and type of habitat, and probability of development. The Dreyer Ranch route (the "experimental" route) was situated in an area scheduled for lignite mining and/or conversion, and sampled habitats typical of the rolling, coulee-disected upland grasslands and the Nelson Creek floodplain. Unfortunately, the poor quality of roads along this route did not allow the route to be run when roads were wet or snow covered. The remaining four routes served as controls, and were located primarily within major types of habitats as follows: Flowing Well, badlands and big sagebrush scablands; Missouri River, floodplain cropland and cottonwood forest; Circle, flat to rolling upland rangeland and dry dropland; and Prairie Elk, creek bottom cropland and sagebrush-grassland. The Circle route was the only official BBS route established by the U.S. Fish and Wildlife Service; it had been run six times since 1968 before this study began.

Standard methods described by Robbins and Van Velzen (1967, 1969) were followed, with minor modifications for non-breeding season runs. Each of the five routes consisted of 50 roadside stations at 0.8 km intervals. Runs began one-half hour before local sunrise, and a three-minute count was made within a 0.4 km radius at each station in sequence.

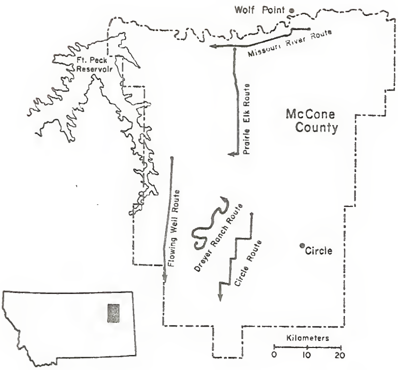


Figure 1. Location of the five BBS routes in the McCone County, Montana study area.

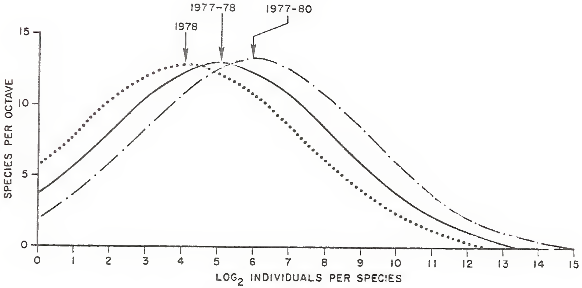


Figure 2. Species curves for one, two, and four years' pooled data for May-July runs of five BBS routes. Arrows indicate position of mode. Note that the curve advances one octave to the right with each successive doubling of sample size.

In 1977, all routes were run monthly (November excluded) except the Dreyer Ranch route, which was run May, June, and July only. In 1978, 1979, and 1980, each route was run monthly May through July. During the four years of the study, 4700 three-minute counts were made during 94 BBS runs. The percentage of the count area falling into each of the habitat categories was estimated in the field at each of the 250 stations, using aerial photographs as reference. Elevation and landmarks were also recorded. All runs were made by the author except during January and December, 1977.

RESULTS AND DISCUSSION

SPECIES INVENTORY

The effectiveness of the BBS technique in sampling bird species composition over a large region is of interest, since compilation of a species list is often a goal of baseline study. The number of species actually present in McCone County at any one time during the study period is unknown. Skaar (1980) has compiled bird species records for the four latilongs including parts of the study area, but these are cumulative totals including all known historic records. The actual number of species present during a given year is certainly much smaller than Skaar's totals. During the course of the study. much field work was conducted by many observers throughout McCone County, and the total number of species encountered by all observers, including observations made in addition to the BBS runs, may be a closer approximation of the actual number of species present.

Even though it sampled less than 2% of the McCone County study area, the BBS was very effective in sampling bird species composition. Of the 139 bird species encountered at some time during the 1977 baseline study, 107 were detected on one or more of the 47 yearlong BBS runs, a 77% sampling efficiency. Of the various species groups, sampling efficiencies were fairly high (88-94%) for permanent residents, winter residents, and summer residents. Migrants and non-breeding summer visitors were less completely sampled (29-33%). Breeding season (May-July 1977) runs were effective in sampling 85-88% of the breeding species known present. Sampling completeness of May-July runs increased considerably for most species groups as the first year's monitoring data were added and somewhat as the second and third year's monitoring data were added. May-July 1977-1980 runs (a total of 60 runs) were effective in sampling 92% of all breeding species and 94% of permanent residents recorded during the entire four-year study.

It is likely that many species were undetected by the BBS runs because certain types of habitats (e.g., Fort Peck Reservoir) were simply not sampled by the routes. This would mean that the method is an even more efficient means of inventorying those habitats which were actually sampled by the routes than the above figures would indicate. In the following section, the actual number of breeding species present in this smaller area sampled by the routes is estimated by a different means, and is compared with the number of species actually detected during the BBS runs.

DESCRIPTION OF THE UNIVERSE SAMPLED

As mentioned above, there is no way of knowing exactly how many breeding bird species were really present in the 25.4 km^2 area sampled by each route; however, this number can be estimated by analysis of the distribution of species abundances in the samples obtained during the runs. The species-abundance relation itself, in fact, provides an accurate description of the "universe" from which the samples were drawn--that is, of the actual breeding bird community present in the 25.4 km^2 sample area.

Preston (1948, 1962) was the first to examine in detail the log-normal species-abundance relation. He noted that when field data are plotted on a graph where the abscissa consists of logarithmic categories of individuals per species (octaves of 1-2, 2-4, 4-8, 8-16, etc. individuals per species) and the ordinate represents the number of species falling into each category, the resultant plots take the form of a normal curve. For small, incomplete samples, the left-hand arm of the curve is truncated at the ordinate (the "veil line"), with the degree of truncation depending on the proportion of the universe which has been sampled. The area under the entire curve represents the theoretical total number of species present in the universe from which the samples were drawn, or S_t. In the truncated curve, the area under that portion to the right of the ordinate approximates the number of species in the sample, and the remaining area represents rare species missed in sampling. An important property of this relation is that, for a fixed universe, doubling sample size tends to simply withdraw the curve one octave to the right without changing its shape. It is thus theoretically possible to estimate the total number of species in the universe sampled, and thus the degree of sampling completeness, based on an incomplete sample.

Lognormal curves were fitted to field data, treating the various routes as samples, using the method of Slocomb et al. (1977). The number of registrations per species was used in the analysis, although it is clear that this measure is quite different than true or even relative abundances (as discussed later), and that the "universe" thus revealed may be a different one than would be obtained using true abundances.

The species curves obtained using pooled 1977-1980 breeding season data for the five routes combined are shown in Figure 2. In 1978, 94 breeding species were registered on May-July runs of the routes, while the species-abundance relation predicts 102 species in the theoretical universe bounded by the curve. Sampling therefore appears to be about 92% complete. When all May-July BBS data for the period 1977-1980 are pooled, the number of breeding species actually encountered rises to 101, while the theoretical number of species is 104. Sampling in this case appears to be 97% complete. As shown in the figure, the curve advances almost exactly one octave to the right as sample size is doubled. Therefore, the BBS method is 92% or more effective in sampling the bird community present in the area defined by the sample radius.

For individual routes, sampling completeness based on 1978 data alone ranges from 62% to 94%. Based on cumulative May-July 1977-1980 data, it ranges from 83% to 93%. The effectiveness of the BBS method can thus be quite variable for individual routes. In general, it increases as more runs of the same route are made. Ecological implications of the shapes of the species curves are discussed later.

CHANGES IN ABUNDANCES OF INDIVIDUAL SPECIES

As mentioned earlier, the number of registrations (r) obtained for each species by the BBS method is by no means a measure of actual abundance, but is related to the actual abundances x by some unknown function $f(x) = r$ which incorporated such species, area, and season-specific variables as conspiciousness, local habitat, vegetative cover, timing in relation to the reproductive cycle, group size, and animal size, to name a few. While it would certainly be interesting to define the functions $f(x)$ for each species and each season, this is not possible without exhaustive effort. Further, definition of $f(x)$ is not necessary to draw ecological conclusions about individual species based on r. It must be emphasized, however, that r is merely a species and season-specific abundance index analagous to the "audiovisual density index" of Beals (1960), and comparisons between species or between monthly replicates must be made with caution.

BBS data allow comparison of the relative abundance index (that is, the number of registrations) between routes and (as long as changes in conspiciousness are taken into account) between seasons. Figure 3 shows, as an example, a plot of monthly changes in sample abundances of the ring-necked pheasant, a permanent resident in the study area, for the five individual routes and for the four control routes combined. It is evident that sample abundances are consistently higher for the Missouri River and Prairie Elk routes, which have the most cropland in conjunction with floodplain forest or tall shrub cover. A curve showing theoretical changes in actual population size throughout the year (Weigand and Jenson 1976) is superimposed on these plots (not to the same vertical scale), and allows comparison of expected pheasant numbers with observed sample abundances. It is noteworthy that sample abundances are high during April and early May, the time of expected low population density, because of the spring peak in rooster crowing activity. Sample abundances dropped off more sharply than expected abundances as crowing declined and hens and broods became more secretive over the summer. Nevertheless, the data clearly display between-route differences in pheasant density which are related to habitat differences and which are consistent from month to month. Several species, such as the ring-necked pheasant, which consistently attain maximum representation on a single route were identified as "indicators" of those particular routes.

The data also allow documentation of year-to-year changes in sample abundances of species or species groups. Figure 4 shows year-to-year changes in May-July average abundance of ring-necked pheasants; note that the relative ranking of the five routes remains consistent from year to year, although the severe winter of 1977-1978 resulted in a significant ($p < .01$, paired t-test) population decline. Figure 5 shows

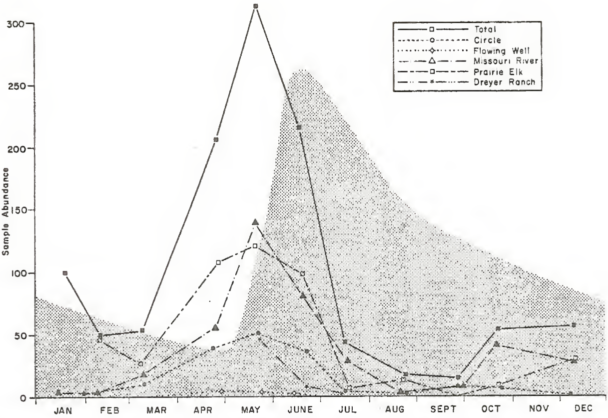


Figure 3. Monthly changes in 1977 sample abundances of ring-necked pheasants for five BBS routes. Shaded area shows theoretical changes in population size throughout the year (not to same vertical scale).

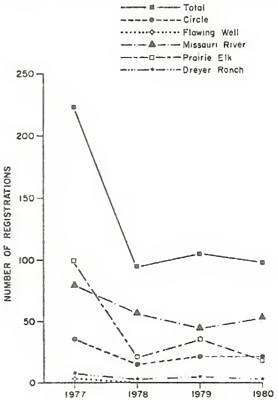


Figure 4. Year-to-year changes in sample abundances of ring-necked pheasants for five BBS routes.

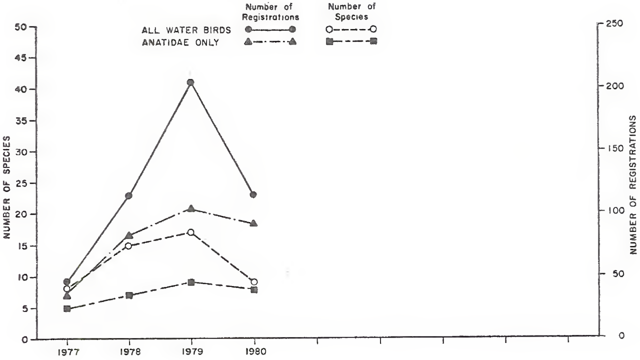


Figure 5. Year-to-year changes in numbers of species and numbers of registrations of water birds recorded on June runs of five BBS routes. Waterfowl use, productivity, and diversity, as measured by a number of independent studies, showed a sharp decline between 1979 (a wet year) and 1980 (a dry year).

weather-related changes in water bird populations from year to year, as revealed by BBS data. In 1977 and 1980, spring conditions were exceptionally dry, and both the number of species and the number of individuals (based on pooled May-July data for the five routes) were relatively low.

BBS data can be used to provide information on species dispersion (Rotenberry and Wiens 1975); Preston and Thompson (1979) suggest that dispersion patterns revealed by BBS data may be useful indicators of changes in patterns of space utilization. However, dispersion patterns were not determined during the present study.

COMMUNITY PATTERNS

BBS data can yield useful information on various aspects of bird community ecology; several examples are discussed below.

Guilds

Bird species encountered on BBS routes were assigned to guilds (Root 1967) based on major food source, foraging stratum, foraging strategy, and nesting strategy. Monthly changes in trophic composition and feeding guilds for the four control routes during the 1977 baseline study are shown in Figure 6 and 7; between-year changes in these same parameters for all five routes combined are shown in Figures 8 and 9. Note that most permanent residents feed primarily on vertebrates or seeds and vegetation; the summer residents which arrive each spring are primarily omnivores and insectivores. Community trophic structure is quite constant from year to year, in spite of yearly differences in weather, vegetation productivity, and small mammal biomass.

Resident Status

Seasonal changes in species numbers of yearlong residents (R), summer residents (S), winter residents (W), and migrants (M) for the four control routes combined are shown in Figure 10. These and other data indicate that the peaks of spring and fall migration occur from mid-April to mid-May and from early September to mid-October, respectively. The majority of species are evidently summer residents from late spring to early fall.

Diversity

A number of diversity parameters were calculated from the BBS sample data. These may be grouped into three broad categories. The first includes measures which are sensitive to the variety of species in the sample, such as species number (S), species richness ($J=(S-1)/\ln N$), the theoretical total number of species predicted by the lognormal species abundance relation (S_t), and the height of the mode of the species curve (S_0). The second includes measures which are sensitive to the equitability of distribution of individuals among species, such as evenness ($e=H'/\ln S$), the logarithmic dispersion factor of the species abundance curve (a), and the logarithmic standard deviation (σ) of the species abundance curve. The third includes "hybrid" measures sensitive to both, notably the Shannon-Weaver index (H'). Factor analysis was used to determine which of these measures were most sensitive to ecological differences between routes. The first factor, which accounted for 65%

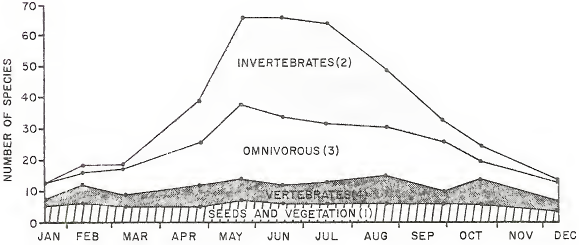


Figure 6. Monthly changes in trophic composition (based on major food source) of bird communities sampled by four BBS routes, 1977 (numbers in parentheses are guild codes).

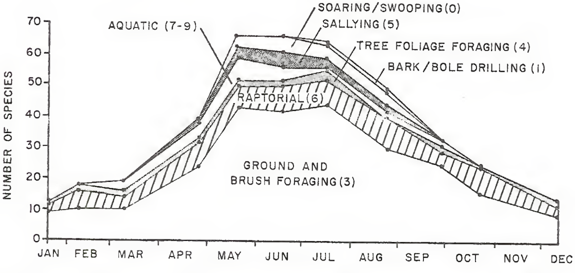


Figure 7. Monthly changes in representation of feeding guilds among bird communities sampled by four BBS routes, 1977 (numbers in parentheses are guild codes).

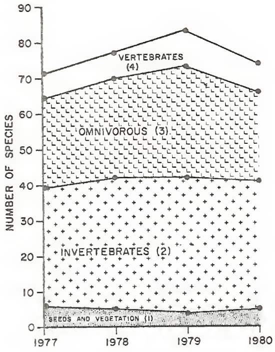


Figure 8. Year-to-year changes in June trophic composition of bird communities sampled by five BBS routes.

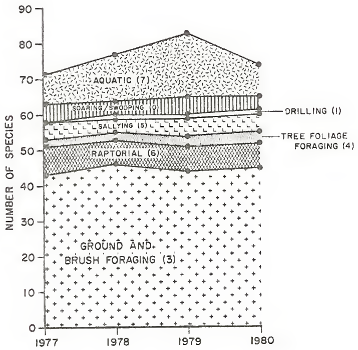


Figure 9. Year-to-year changes in June representation of feeding guilds among bird communities sampled by five BBS routes. With the exception of the aquatic feeding guild, community structure was remarkably stable over the four-year period. The sharp decline in the aquatic feeding guild parallels that shown in Figure 5.

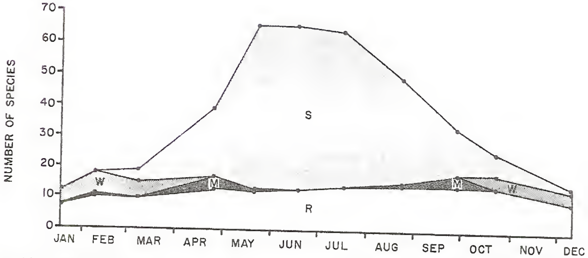


Figure 10. Monthly changes in resident status of bird communities sampled by four BBS routes, 1977 (R=yearlong residents; S=summer residents; W = winter residents; M=migrants).

of the variation among data sets, was closely related to the variety of species in the sample; the community parameter with the highest loading on this factor was J. The second factor accounted for an additional 24% of the variations, and was closely related to equitability. The logarithmic standard deviation (σ) showed the highest loading on this factor. Therefore, J and σ appear to be the most reliable measures of ecological differences among these particular routes.

A graph showing monthly changes in species richness (J) for the five routes during the 1977 baseline study is shown in Figure 11. Note that the ordination of routes is remarkably constant from month to month; this feature is also apparent in the case of year-to-year changes (Figure 12).

The close relation of the parameters of the lognormal species-abundance relation to species diversity is noteworthy, as the diversity of a community is related to the shape of the species curve. A more diverse community will in general reveal 1) a taller species curve, reflecting greater variety; 2) a narrower species curve, reflecting greater equitability, and 3) a species curve encompassing a larger area. Examination of Figure 13 allows quick visual comparison of various ecological features of the five routes. It is evident from this figure that the floodplain forest community sampled by the Missouri River Route has a high species variety and high equitability, while the badlands community sampled by the Flowing Well route has much lower values for these parameters. The Circle route also has low species variety and equitability, but its species curve encompasses a relatively large area. The lognormal curves may therefore provide an ideal monitoring tool: they are sensitive to community attributes, allow easy visual comparison of samples, and provide a precise "fingerprint" of the bird community (and hence of environmental conditions) which varies little from year to year in the absence of disturbance. Curves for different routes are shaped differently and distinctively (Fig. 13), while curves for individual routes are remarkably constant in shape from year to year (Fig. 14).

Nagasawa and Nuorteva (1974) suggested that the failure of field data to provide a good fit to the lognormal curve can serve as an indicator of environmental disturbances. However, Preston (1980) found that failure to conform closely to the lognormal distribution is routinely encountered in relatively pristine environments. Data obtained in this study indicates that goodness of fit varies widely for different runs of the same route, and seems to be related to random sampling variation rather than to environmental or community features.

Habitat Relations

Pearson product-moment correlation coefficients among bird species abundances and habitat variables at individual stops revealed a large number of highly significant ($p < .001$) correlations. An attempt to further elucidate habitat requirements of individual species by stepwise multiple regressions using the same data was not as successful; the twelve habitat variables used in the regression analysis each accounted for only 5% to 43% of the variation in sample abundances for those species analyzed. Multiple regression revealed a significant relation between habitat, time (in relation to start of route), and species number, as shown in the following equation, which accounts for 36% of the variation observed:

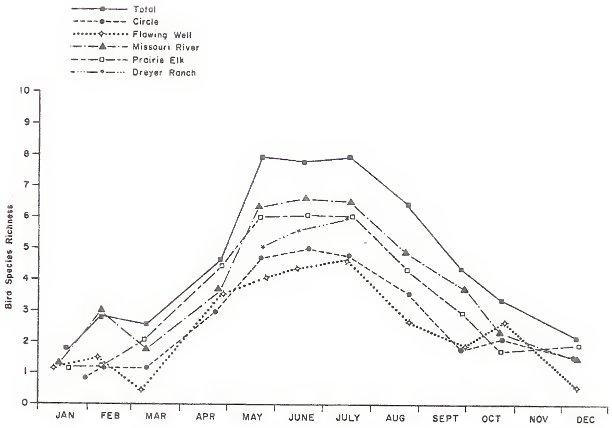
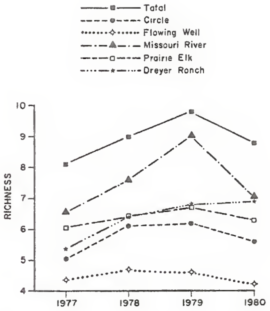


Figure 11. Monthly changes in bird species richness for 1977 runs of five BBS routes.



Fiqure 12. Year-to-year changes in June bird species richness for five BBS routes.

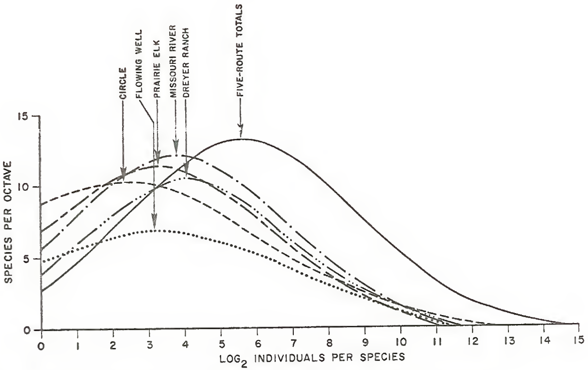


Figure 13. Species curves for individual BBS routes (based on pooled May-July 1977-1979 data). Arrows indicate position of mode.

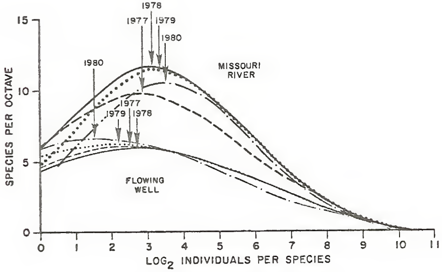


Figure 14. Comparison of yearly changes in species curves for the Missouri River (top) and Flowing Well (bottom) Routes (based on pooled May-July data for each year).

Number of Species = 20.9 - (0.12 x time) + (0.42 x percentage of count area having tree and tall shrub cover).

Factor analysis was used to create an ordination whereby community patterns may be more easily visualized (Figure 15). The first two factors, used as axes of this ordination, together accounted for 20.3 percent of the observed variation in samples. Factor one appears primarily to reflect differences in foliage height diversity, progressing from open grassland or bare ground on the extreme left through low shrubland, taller shrubs, and finally cottonwood forest with a tall shrub understory on the extreme right. Factor two seems related to habitat homogeneity, canopy coverage, and topographic diversity. Complex, heavily dissected badlands receive high positive factor scores, and flat or rolling areas with high grass cover and high homogeneity receive high negative scores. While habitat variables and bird sample abundances were both included in the factor analysis, only birds are shown in the ordination. In most cases, 1977 and 1978 bird data were treated separately to reveal year to year differences; in some cases, different months were treated separately as well.

Several groupings of species showing similar habitat requirements are clearly evident in this ordination. In the lower left are the characteristic grassland species which nearly always occur together in flat-to-rolling, open grasslands. In the upper left is a group of three species which are characteristic of the heavily dissected badlands and scablands. A fairly large group of species characteristic of tall shrub and tree shrub habitats is evident on the far right. In general, species whose sample abundances are highly correlated appear close together in the ordination, and the strongest indicator species are those with the highest scores. As shown by the figure, habitat preferences for most species were remarkably constant both from month to month and from year to year. Only seven species showed major differences as indicated by a Euclidean distance $\geq$ 0.02 in the factor scores. The most spectacular habitat shift was shown by the Lark Bunting, which preferred flat to rolling grasslands along the Circle and Dreyer Ranch routes in 1977 and sagebrush-badland habitats along the Flowing Well route in 1978.

OBSERVER BIAS

A drawback of the BBS technique is its strong dependence on observer bias in estimating sample abundances. Data gathered by two different observers for the same route at the same time may be considerably different, even if both observers are equally skilled. In order to gain some insight into the importance of observer bias, the percent similarity of results for the Circle route between subsequent runs was determined using the coefficient of similarity as defined by Bray and Curtis (1957). Prominence values (Beals 1960) were used in place of sample abundances.

Between-year similarities for 1968-1979 runs of the Circle Route ranged from 0.32 to 0.89 (Figure 6). This wide variation may reflect ecological differences in breeding bird populations from year to year,

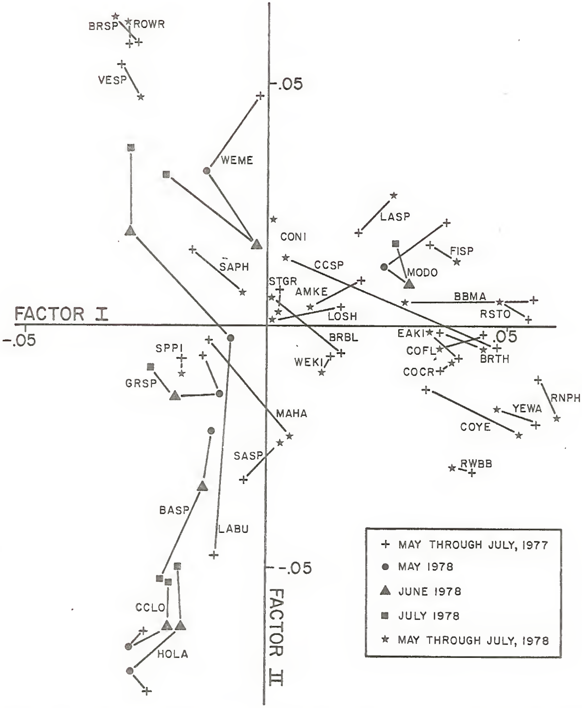


Figure 15. Ordination of selected species (indicated by four-letter abbreviations) along Factors I and II, showing 1977-1978 changes.

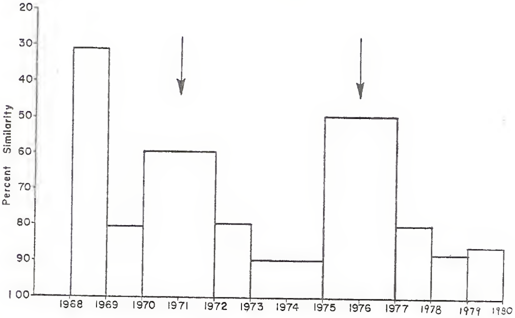


Figure 16. Between-year similarity in percent for 1968-1980 June runs of the Circle BBS route. Arrows indicate changes in observers.

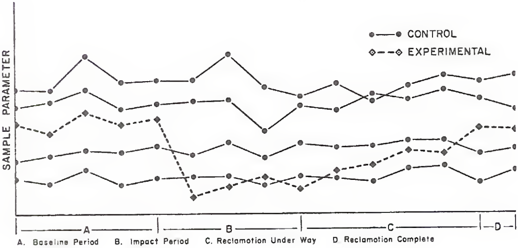


Figure 17. Hypothetical plot of BBS data over many years, showing a possible response of the experimental route to development-related impact.

but is most likely due to changes in observers and observer bias. Figure 6 shows a general increase in similarity between 1968-1970, between 1972-1975, and between 1977 and 1980, as the observers became more familiar with the birds and the route. Observers were changed between 1970 and 1972 and again between 1975 and 1977, and this change is accompanied by a sharp drop in similarity (note: no runs were made in 1971, 1974, or 1976). This demonstrates the extreme importance of maintaining observer continuity for long-term monitoring.

IMPACT ANALYSIS

Since no mining activity has yet taken place in the study area, it is impossible to determine the sensitivity of the BBS techniques in detecting mining-related or other changes in the parameters discussed above. However, such a change might be expected to produce a change in one or more parameters for the Dreyer (experimental) route, as shown in Figure 7. The relative positions of the four control routes on such a graph are likely to remain unchanged, although the controls may undergo considerable concurrent change due to year-to-year variation in weather and phenology. The eventual restoration of the original ordination of the five routes should provide substantial evidence for the success of reclamation, as shown by D in Figure 7.

It is likely that the BBS would be sensitive to widespread community changes--for example, those due to emissions, broad land use changes, increased traffic, increased hunting pressure, etc.--than most single-species study techniques. Although this has yet to be demonstrated, impacts affecting many segments of the community (e.g., emissions affecting insect abundances, vegetation structure, small mammal abundances) should be reflected by distinct changes in bird community parameters as measured by the BBS. The problem of demonstrating causality would remain, but examination of the types of birds most affected would provide valuable clues in tracing the cause-and-effect chain of the impact. An example of one means of documenting impacts using BBS data would be use of multiple regression to define relationships between emission levels and the percent change between pre-and post-project sample abundances for a given BBS station. Hopefully, these types of data would be useful in mitigating and/or compensating the wildlife impacts of development.

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